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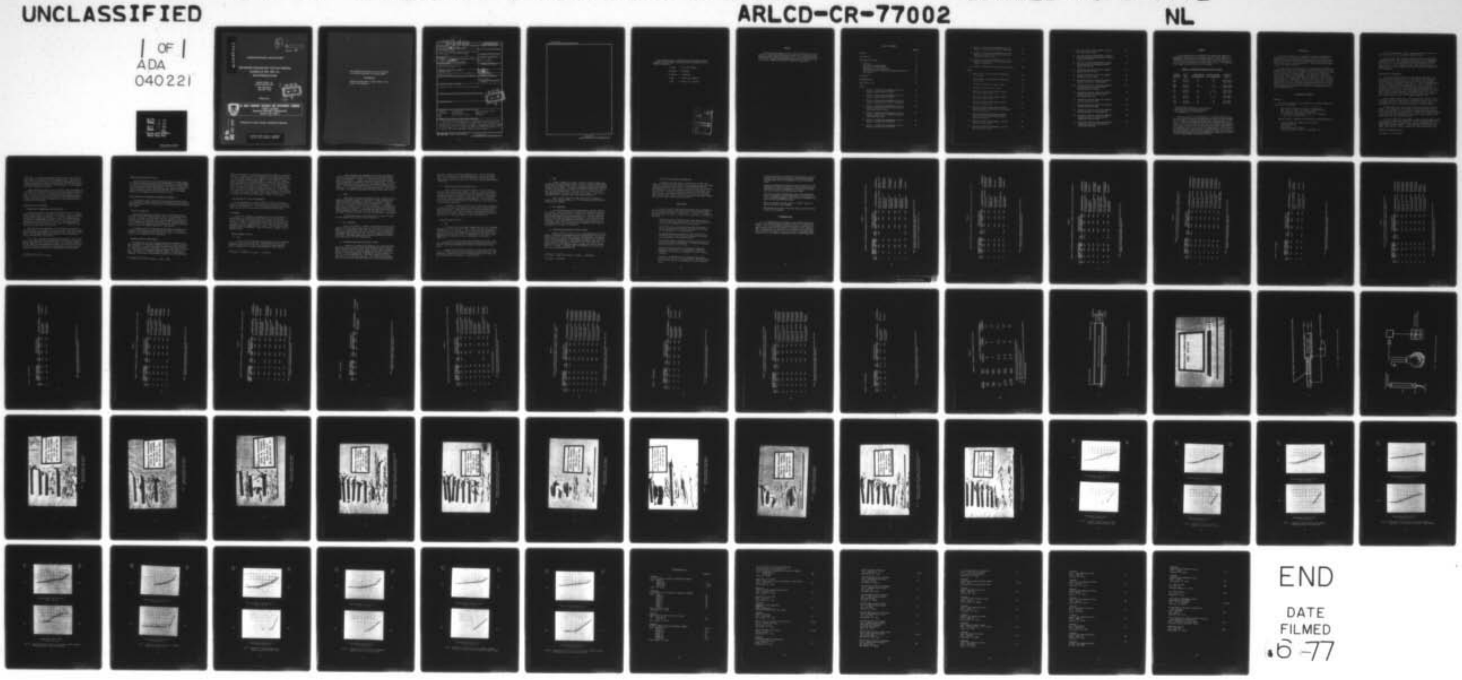

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DETONATION PROPAGATION TESTS ON AQUEOUS SLURRIES OF RDX, HMX, M-1, AND NITROCELLULOSE

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US ARMY ARMAMENT RESEARCH AND DEVELOPMENT COMMAND
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The objective of this program was to investigate the detonation propagation characteristics of aqueous slurries of RDX, HMX, M-1 and two types of nitrocellulose in 2 inch, schedule 40, stainless steel pipes of various lengths. Two operational modes were studied; the dynamic or pumping mode and, the static or settled slurry mode. The dynamic condition was simulated by adding an inert gelling agent to a homogeneous, aqueous, explosive slurry.

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The following metric conversions, which conform to ASTM Standard E-380-74, Metric Practice Guide, are provided for the readers convenience.

1 inch	=	2.54×10^{-2} meters
24 inches	=	.61 meters
40 inches	=	1.02 meters
1 gal	=	2.785×10^{-3} meters^3
5 gal	=	18.925×10^{-3} meters^3

PREFACE

The detonation propagation test results presented on this program are a continuation of the work presented in Picatinny Arsenal Technical Report 4584 dated November 1973. This previous work categorized the detonation propagation characteristics of aqueous slurries of TNT, Composition B, and M-9 and M-10 propellants.

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SUMMARY

A test program has been performed to establish the detonation propagation characteristics of aqueous slurries of RDX, HMX, M-1 propellant, and two types of nitrocellulose in 2-inch, schedule 40, stainless steel pipes 24 and 40 inches long. The slurry concentrations tested were prepared on a weight percent basis. The following table summarizes the results of this program:

Summary of detonation propagation test results

Sample material	Slurry type	Concentration - weight percent No propagation	Concentration - weight percent Full propagation	Detonation class
RDX	Gelled	20	30	High order
RDX	Settled	10	20	High order
HMX	Gelled	20	30	High order
HMX	Settled	5***	5 - 10	High order
M-1	Gelled	30	40	High order
M-1	Settled	30	40 - 45	High order
NC*	Gelled	55	60 - 65	Low order
NC*	Settled	55	65	Low order
NC**	Gelled	55	65	Low order
NC**	Settled	55	65	Low order

*Nitrocellulose containing cotton linters
**Nitrocellulose containing wood pulp
***No propagation in 2 of 3 trials

From the results of this program it is concluded that for the specific conditions tested, aqueous, gelled slurries of RDX and HMX will not support a propagating detonation at concentrations of 20% or less. In the settled slurry condition, the non-propagating concentration is 10% less for RDX and less than 5% for HMX. M-1 propellant test results indicate that for both the gelled and settled slurries no propagation occurs at or below 30% concentrations. Nitrocellulose does not propagate a detonation at concentrations of 55% or less in both the gelled and settled slurry conditions. There is no difference in sensitivity between the nitrocellulose containing cotton linters and the nitrocellulose containing wood pulp.

INTRODUCTION

This report summarizes the results of a series of experiments performed by Hazards Research Corporation, Denville, New Jersey, under the technical direction of the Modernization and Special Technology Division of the Manufacturing Technology Directorate located at Picatinny Arsenal, Dover, New Jersey. The work was funded under Contract No. DAAA21-73-C-0772.

The objective of this program was to investigate the detonation propagation characteristics of aqueous slurried of RDX, HMX, M-1 propellant and two types of Nitrocellulose in 2-inch, schedule 40, stainless steel pipes of various lengths. Two operational modes were studied; the dynamic or pumping mode and, the static, or settled slurry mode. The dynamic condition was simulated by adding an inert gelling agent to a homogeneous, aqueous, explosive slurry. Information generated by this program will be used in support of the United States Army's munitions manufacturing and loading facilities by supplying data to aid in the design and operation of the feed system for the propellant and explosive incinerators installed at various Army Ammunition Plants.

EXPERIMENTAL PROGRAM

Materials

The following materials were supplied by Picatinny Arsenal for use in this test program:

RDX, Finely divided, 22.7% water, Lot HOL-21-22
HMX, Finely divided, 24.8% water, Lot HOL-SR-653-61
M-1, Granular, No. 8 mesh, Lot RAD 68869
nitrocellulose containing wood pulp, 12.2% Nitrogen
41% water, Lot HEP-6-38Y

Hazards Research Corporation furnished the following materials:

2-inch schedule 40, seamless, 304 SST pipe
E-83 blasting caps
RDX boosters
Detonation Velocity Probes
CMC gelling powder, type 7H, by Hercules, Inc.

Two 2-inch diameter by 1-inch[1] long RDX pellets were used as a booster in each test. Each pellet weighed 75 grams.

In those tests that simulated a dynamic flow system condition, a gelling agent was used to suspend the explosives in a homogeneous mixture with water. The gelling agent used was Hercules Cellulose Gum Type 7H. It is 99.5% purified sodium carboxymethylcellulose (CMC), which is a water soluble polymer. When mixed with water at a concentration of 1.5% by weight, it yields a gel with a viscosity of 6000 centipoises.

Description of Experiments

All tests performed during this program were conducted in the test setup shown in Figures 1 and 2. The sample slurry was mixed thoroughly and carefully poured into the open end of an upright, 2-inch, schedule 40, stainless steel pipe. A plastic diaphragm taped to the bottom end provided a leak-proof seal. After the pipe was filled, a second plastic diaphragm was taped over its open end. A detonation velocity probe was then inserted through the plastic diaphragm and into the slurry. The probe-diaphragm interface was sealed with a plastic sealing compound. Two proble lengths were used, 24 inches and 40 inches. These lengths were dictated by the length of pipe tested since they had to be of equal numerical value.

For the gelled slurry tests, the loaded pipe was placed in the horizontal position, charged with a 150 gram RDX booster plus an E-83 cap, armed and fired. The resultant detonation velocity trace was displayed on an oscilloscope and recorded by a Polaroid camera.

Settled slurry tests followed the same basic procedure outlined above. The exception to the procedure was that after the velocity probe was positioned, it was necessary to maintain a mixed slurry up to the time when the pipe was placed in the horizontal firing position. Once placed, the test required that the solids in the aqueous slurry settle out into a fairly uniform layer.

In order to meet this requirement, a series of preliminary screening tests were performed to establish the settling characteristics of each sample material. Sample aqueous slurries containing 10% solid sample material were prepared. A 48-inch[2] long, 2-inch inside diameter, Pyrex tube was used to simulate the physical confines of the

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[1] 1 inch = 2.54×10^{-2} meters.

[2] 48 inches = 1.2192 meters.

steel pipe. Each slurry was poured into the Pyrex tube, which was then vigorously shaken about its longitudinal axis. The tube was then placed on a horizontal surface and the settling pattern of its contents was observed. Results revealed that the RDX, HMX, and M-1 settled immediately upon cessation of pipe motion. The nitrocellulose took 10 minutes to settle.

These preliminary settling tests resulted in the development of a technique for continuously oscillating the pipe prior to its placement on a level surface. Once placed, the solid contents of the pipe settled out in a fairly predictable and reproducibly uniform level. In addition, these tests resulted in the establishment of a standard settling time of 15 minutes for all settled slurry tests performed on this program.

Description of Test Methods

Preparation of Homogeneous, Gelled Slurries

The gelled slurries (consisting of the material to be tested, gelling agent and water) were made in two steps. First, a 5-gallon[3] batch of gelled water was prepared. This mixture contained 1.5% by weight of CMC polymer and 98.5% water. Next, the sample material was added to a predetermined quantity of gelled water to yield the required percentage called for in the test. After approximately 20 minutes of low speed agitation, the slurry was homogeneous and ready to be poured into a test fixture.

Once the slurry was prepared, it was constantly stirred at a low speed until it was poured into the test pipe. Total time elapsed between loading and detonating each pipe was never more than 17 minutes. This procedure reduced the probability of any significant settling of the sample in the pipe.

In all tests the percentage composition reported is the percentage of dry sample material contained in the total slurry weight of water, sample material, and gelling powder. The moisture content of the RDX, HMX and nitrocellulose was taken into account in all calculations of explosive weight percent concentration. The M-1 was received dry and did not require a correction for moisture content.

[3] 5 gallon = 18.925×10^{-3} meters^3.

Preparation of Settled Slurries

The settled slurries were individually mixed by slowly adding the required quantity of explosive or propellant to a weighed amount of water. An air operated mixing motor provided the variable speed drive required for the mixing operation. The slurry was agitated in a plastic bucket by three, vertically mounted, plastic impellers. Visual inspection provided the indication that all of the sample material was thoroughly wetted and ready for test.

Characterization of Detonation Propagation Phenomena

The distance that a booster-initiated, high or low order reaction propagated through the slurries was determined by two techniques; physical inspection of the pipes after a test and detonation velocity measurements.

Physical Inspection

High order detonations produce a totally shrapnellized pipe. Low order detonations usually produce long, wide, fragmented strips of pipe. Low order, decaying type reactions, normally result in a peeling back of the pipe wall along its longitudinal axis beginning at the booster end and no physical damage to the remaining pipe section. In addition, unreacted slurry is expelled onto the surrounding area due to the impulse generated by the booster.

A reference point for evaluation of the physical damage is obtained by testing a pipe filled with gelled water. This provides evidence of the damage caused by the booster charge. All other test results can be compared to this datum point.

Detonation Velocity Measurement

The detonation velocity of sample material was measured using the continuous velocity probe developed by the U.S. Bureau of Mines.[4] This technique is a convenient method of determining the capability of a material to sustain a high-order reaction. The sample is placed in a steel pipe with a booster charge set against the base of the pipe. The booster is separated from the sample by a thin plastic diaphragm. Initiation of the booster triggers an oscilloscope which

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[4] J. Ribovich, et al AIAA Journal, 6, 1260, (1968).

monitors the output of a constant-current power supply as a function of time. A detector circuit consisting of a fine skip-wound resistance wire passed through a thin aluminum tube is mounted on the major axis of the tube containing the sample. As the shock wave passes along the detector, the aluminum tube is crushed onto the resistance wire, shortening the circuit. Essentially, all the resistance of the circuit is in the wire, which is uniform, so the power supply adjusts the voltage to maintain constant current. The voltage-time trace is readily convertible to detonation velocity. If no detonation occurred in the sample, the probe circuit registers the velocity of sound in the sample. Figures 3 and 4 show the details of the velocity probe and the system's operational concept, respectively.

Verification of Limits of Propagation

The no propagation, decaying detonation, and full detonation weight concentrations were established for the five materials tested using 24-inch long pipes.[5] If the detonation decayed in the 40-inch long pipe, the test was repeated at a 5% higher concentration.

Test Results

A total of 75 detonation propagation tests were performed on this program, 36 on gelled slurries and 39 on settled slurries. Figures 5 through 14 are photographs of the pipes in their post-test condition. Figures 15 through 19 contain typical detonation velocity traces for each sample material. Each figure contains one non-propagating and one propagating test result. The test data is presented in Tables 1 through 10. Table 11 provides a summary of test program results.

Gelled, Aqueous Slurries

1. RDX

A series of five detonation propagation tests were performed on aqueous, gelled slurries of RDX. One additional test was performed on gelled water in order to establish the datum point for physical damage for all of the tests performed on this program.

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[5]24 inches = .61 meters, 40 inches = 1.02 meters.

Table 1 presents the tabulated test results and Figure 15 contains the detonation velocity traces for the 20% and 30% RDX slurry concentrations. Figure 5 is a photo of the pipes in their post-test condition. It can be seen that the gelled RDX slurries did not propagate a detonation at the 20% concentration. At the 25% concentration there was an increase in the physical damage to the pipes. A high order detonation (5000 m/sec) occurred at the 30% concentration. The repeat test at the 30% concentration, in a 40-inch long pipe, confirmed the high order detonation result (4930 m/sec).

2. HMX

The limits of detonation propagation were characterized for aqueous, gelled HMX slurries in five tests. Table 2 presents the tabulated results and Figure 16 contains the detonation velocity traces for the 20% and 30% HMX slurry concentrations. Figure 6 shows all five pipes in their post-test condition. No propagation was evident at the 20% level. At the 25% concentration the physical damage increased slightly. A high-order detonation occurred at the 30% concentration in both the 24 and 40-inch long pipes. Detonation velocities for these two tests were 5410 and 5250 m/sec, respectively.

It should be noted at this point that the results for HMX and RDX aqueous, gelled slurries were identical.

3. M-1 Propellant

Table 3 and Figure 17 contain the tabulated results and detonation velocity traces respectively for this series of six tests. Figure 7 is a photograph of the pipes in their post-test condition. The results indicate that there is a difference of 10% between the non-propagating concentration (30%) and the propagating concentration (40%). High-order detonations occurred in both the 24 and 40-inch long pipes at the 40% concentration.

4. Nitrocellulose Containing Cotton Linters

A series of 10 detonation propagation tests were performed on aqueous, gelled nitrocellulose which contained cotton linters. Table 4 presents the test results while Figure 18 contains representative velocity traces. Physical damage to the pipes is shown in Figure 8. The non-propagating concentration for this material was 55%. At the 60% concentration a low-order detonation occurred (2610 m/sec) in the 24-inch long pipe. The repeat of this concentration in the 40-inch long pipe resulted in a decaying detonation.

The last 5 inches of the pipe remained intact. It was, therefore, necessary to perform a 65% concentration test in the 40-inch long pipe. This resulted in a low-order detonation (2422 m/sec) which fragmented the pipe into strips 4 to 18 inches long and approximately 1-inch wide.

5. Nitrocellulose Containing Wood Pulp

Table 5 presents the tabulated results of the tests performed on this phase of the program. Figure 19 contains detonation velocity traces for the non-propagating concentration (55%) and the propagating concentration (65%). Post-test condition of the pipes is shown in Figure 9. Results indicate that there is a 10% difference between the non-propagating concentrations. All detonations were low-order (2610 and 2910 m/sec) and occurred at 65% in both the 24 and 40-inch long pipes.

It should be noted that there was no significant difference in test results due to the presence of wood pulp or cotton linters in the Nitrocellulose. Both samples had the same non-propagating concentration (55%). The slight difference in propagating concentrations (5%) is probably a purely statistical phenomena which could be eliminated if a sufficient number of tests were performed.

Settled, Aqueous Slurries

1. RDX

A series of five detonation propagation tests were performed on aqueous, settled slurries of RDX. Table 6 presents the tabulated data for this series of tests. Figure 20 presents the detonation velocity traces for the propagating concentration (20%) and the non-propagating concentration (10%). A photograph of the pipes as they appeared after completion of the test program is presented in Figure 10.

It can be seen that high order detonations occurred at the 20% concentration and decaying detonations occurred below that level. The 20% concentration propagated in both the 24 and 40-inch long pipes.

Comparing these results with those of the gelled, RDX slurries, it is seen that the settled slurries are more sensitive. They propagate a detonation at the 20% concentration while it requires a 30% concentration to propagate in a gelled slurry.

2. HMX

Table 7 contains the results for this series of eight tests on aqueous, settled slurries of HMX. Figure 21 contains typical detonation velocity traces while Figure 11 presents the post-test physical condition of the pipes. A high-order detonation (6120 m/sec) occurred at the 5% concentration (less than 0.25 inches[6] settled layer thickness) in one of three trials. The pipe was split into two pieces, each approximately 4 inches wide and 22 inches long.[7] Tests at concentrations up to 25% all yielded high-order detonations.

These results suggest that HMX should not be allowed to settle out in a process pipeline. It is the most sensitive material tested on this program.

3. M-1 Propellant

A series of seven tests were performed on aqueous, settled M-1 slurries. Table 8 contains the tabulated results and Figure 22 presents typical velocity traces. Figure 12 is a photo of the pipes after being subjected to the propagation tests. The 30% concentration did not allow a detonation to propagate. Some propagation was evident at 35% and full propagation occurred at 40% in the 24-inch long pipes. The repeat test in the 40-inch long pipe produced a decaying detonation. The concentration was increased to 45% where it propagated at a velocity of 5640 m/sec.

4. Nitrocellulose Containing Cotton Linters

Results for this series of 10 tests are presented in Table 9. Figure 23 contains the propagating and non-propagating velocity traces. Figure 13 presents the physical evidence remaining after the completion of this test series. No propagation occurred up to a concentration of 55% nitrocellulose. Some reaction occurred at 60% and a low-order detonation (2910 m/sec) occurred at 65%. This result was repeated in the 40-inch long pipe where a detonation velocity of 2860 m/sec was recorded. It appears that this material is not very sensitive up to concentrations of 55%.

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[6].25 inches = $.635 \times 10^{-2}$ meters, 4 inches = .102 meters

[7]22 inches = .56 meters

5. Nitrocellulose Containing Wood Pulp

Examination of the results of this series of nine tests (Table 10) reveals that the results are identical to those for nitrocellulose containing cotton linters. The propagating and non-propagating velocity traces shown in Figure 24 reveal that the material propagates at the 65% concentration and does not propagate at the 55% level. Low-order detonation velocities of 3115 m/sec and 3050 m/sec were recorded at the 65% level in 24 and 40-inch long pipes respectively. Figure 14 presents the physical evidence remaining after the completion of this test series.

CONCLUSIONS

As a result of the 75 detonation propagation tests performed on aqueous slurries containing RDX, HMX, M-1 or nitrocellulose which are confined in horizontal, 2-inch diameter, schedule 40, stainless steel pipes up to 40 inches in length, it is possible to conclude the following:

Gelled RDX slurries propagate high order detonations at 30% (by weight) RDX concentrations, partially propagate at 25% and do not propagate at 20% concentrations.

Settled RDX slurries propagate high-order detonations at 20% RDX concentrations, partially propagate at 15% and do not propagate at 10% concentrations.

Gelled HMX slurries propagate high-order detonations at 30% HMX concentrations, partially propagate at 25% and do not propagate at 20% concentrations.

Settled HMX slurries propagated high-order detonations at and above 10% HMX concentrations. A detonation occurred at the 5% level in 1 of 3 trials.

Gelled M-1 propellant slurries propagate high-order detonationa at the 40% M-1 concentrations, partially propagate at 35% and do not propagate at 20-30% concentrations.

Settled M-1 propellant slurries propagate high-order detonations at 40-45% M-1 concentrations, partially propagate at 35-40% and do not propagate at 15-30% concentrations.

Gelled nitrocellulose (containing cotton linters) slurries propagate low-order detonations at 60-65% nitrocellulose concentrations and do not propagate at 10-55% concentrations.

Settled nitrocellulose (containing cotton linters) slurries propagate low-order detonations at 65% nitrocellulose concentrations, partially propagate at 60% and do not propagate over the 10% to 55% concentration range.

Gelled and settled nitrocellulose (containing wood pulp) slurries propagate low-order detonations at 65% concentrations, partially propagate at 60% and do not propagate over the 10 to 55% concentration range.

HMX in an aqueous, settled slurry is the most sensitive material tested on this program.

RDX and HMX are the most sensitive aqueous, gelled slurries tested on this program.

RECOMMENDATIONS

It is recommended that an automatic water flush system be installed in any process piping system that contains an aqueous HMX slurry. Loss of system pressure should activate a valve which releases pressurized water and flushes the contents of the pipeline into a holding tank. In addition, as a standard safety procedure, none of the other explosive slurries tested on this program should be processed at the weight concentrations that yielded detonations.

Table 1

Results of detonation propagation tests on aqueous, gelled slurries of RDX

Test No.	Slurry Composition Wt. (%) RDX	Wt. (gms) H_2O	Wt. (gms) RDX	Pipe Length	Measured Detonation Velocity (m/sec.) Initial	Midpoint	Final	Physical Evidence	Conclusion
1	0	1320	0	24 in.	2390	1490	590	18 in. O. K., 6 in. peeled at booster end	Booster calibration test
2	20	1162	291	"	4810	1590	1320	16.5 in. O. K., 5 in. peeled, 2.5 in. shrapnellized	Detonation did not propagate
3	25	1117	372	"	4900	1670	1350	14.5 in. O. K., 6 in. peeled, 3.5 in. shrapnellized	Detonation did not propagate
4	30	1068	458	"	5000	5000	5000	Pipe completely shrapnellized	Detonation
5	20	1162	291	"	4020	1620	1140	15.5 in. O. K., 6 in. peeled, 2.5 in. shrapnellized	Detonation did not propagate
6	30	1782	764	40 in.	4930	4930	4930	Pipe completely shrapnellized	Detonation

Note: All tests were performed using a 150 gm. RDX booster and 2 inch, schedule 40, stainless steel pipe (Type 304).

To convert inches to millimeters, multiply by 25.40

Table 2

Results of detonation propagation tests on aqueous, gelled slurries of HMX

Test No.	Slurry Composition Wt. (%) HMX	Slurry Composition Wt. (gms) H_2O	Slurry Composition Wt. (gms) HMX	Pipe Length	Measured Detonation Velocity (m/sec.) Initial	Measured Detonation Velocity (m/sec.) Midpoint	Measured Detonation Velocity (m/sec.) Final	Physical Evidence	Conclusion
7	20	1166	292	24 in.	3320	1700	830	16 in. O. K., 8 in. peeled at booster end	Detonation did not propagate
8	25	1124	375	"	3640	1770	1550	14.5 in. O. K., 7 in. peeled, 2.5 in. shrapnellized	Detonation did not propagate
9	30	1077	462	"	5410	5410	5410	Pipe completely shrapnellized	Detonation
10	20	1166	292	"	3780	1810	1180	15 in. O. K., 9 in peeled at booster end	Detonation did not propagate
11	30	1799	772	40 in.	5250	5250	5250	Pipe completely shrapnellized	Detonation

Note: All tests were performed using a 150 gm. RDX booster and 2 inch, schedule 40, stainless steel pipe (Type 304).

Table 3

Results of detonation propagation tests on aqueous, gelled slurries of M-1 propellant

Test No.	Slurry Composition Wt. (%) M-1	Wt. (gms) H_2O	Wt. (gms) M-1	Pipe Length	Measured Detonation Velocity (m/sec.) Initial	Midpoint	Final	Physical Evidence	Conclusion
12	20	1123	281	24 in.	3690	1580	870	16 in. O. K., 5 in. peeled, 3 in. shrapnellized	Detonation did not propagate
13	40	899	600	"	4675	4675	4675	Pipe completely shrapnellized	Detonation
14	30	1014	435	"	4440	1770	1040	13 in. O. K., 4 in. peeled, 7 in. shrapnellized	Detonation did not propagate
15	35	958	516	"	4220	2330	900	4 in. O. K., 8 in. peeled, 12 in. of 0.5 - 1 in. wide fragment strips	Decaying detonation
16	30	1014	435	"	3840	1730	970	12 in. O. K., 11 in. peeled, 1 in. shrapnellized	Detonation did not propagate
17	40	1498	1000	40 in.	4510	4510	4510	Pipe completely shrapnellized	Detonation

Note: All tests were performed using a 150 gm. RDX booster and 2 inch, schedule 40, stainless steel pipe (Type 304).

Table 4

Results of detonation propagation tests on aqueous, gelled slurries of nitrocellulose containing cotton linters

Test No.	Slurry Composition Wt. (%) N. C.	Wt. (gms) H_2O	Wt. (gms) N. C.	Pipe Length	Measured Detonation Velocity (m/sec.) Initial	Midpoint	Final	Physical Evidence	Conclusion
18	10	1469	163	24 in.	1960	1160	1160	17 in. O. K., 7 in. peeled at booster end	Detonation did not propagate
19	20	1123	281	"	2540	1176	986	16 in. O. K., 8 in. peeled at booster end	Detonation did not propagate
20	30	825	354	"	1840	660	310	16 in. O. K., 8 in. peeled at booster end	Detonation did not propagate
21	40	530	354	"	4500	590	590	15 in. O. K., 8 in. peeled 1 in. shrapnellized	Detonation did not propagate
22	50	363	363	"	3320	760	350	15 in. O. K., 7 in. peeled 2 in. shrapnellized	Detonation did not propagate
23	55	338	414	"	2250	620	310	13 in. O. K., 7 in. peeled 4 in. shrapnellized	Detonation did not propagate
24	60	267	400	"	2610	2610	2610	0.5 - 1.0 in. wide frag. strips of random length	Detonation

Note: All tests were performed using a 150 gm. RDX booster and 2 inch, schedule 40, stainless steel pipe (Type 304).

Table 4 (Continued)

Test No.	Slurry Composition Wt. (%) N. C.	Wt. (gms) H_2O	Wt. (gms) N. C.	Pipe Length	Measured Detonation Velocity (m/sec.) Initial	Midpoint	Final	Physical Evidence	Conclusion
25	60	303	455	40 in.	2490	2490	830	5 in. O.K., 13 in. peeled, 22 in. of 1 in. wide frag. strips	Decaying detonation
26	65	257	478	"	2422	2422	2422	1 in. wide frag. strips, 4 to 18 in. long	Detonation
27	71	153	377	24 in.	2770	2770	2770	1 in. wide frag. strips, 3 to 10 in. long	Detonation

Note: All tests were performed using a 150 gm. RDX booster and 2 inch, schedule 40, stainless steel pipe (Type 304).

Table 5

Results of detonation propagation tests on aqueous, gelled slurries of nitrocellulose containing wood pulp

Test No.	Slurry Composition Wt. (%) N. C.	Slurry Composition Wt. (gms) H_2O	Slurry Composition Wt. (gms) N. C.	Pipe Length	Measured Detonation Velocity (m/sec.) Initial	Measured Detonation Velocity (m/sec.) Midpoint	Measured Detonation Velocity (m/sec.) Final	Physical Evidence	Conclusion
28	10	1469	163	24 in.	1950	1110	1110	17 in. O. K., 7 in. peeled at booster end	Detonation did not propagate
29	20	1123	281	"	2610	1215	1010	16 in. O. K., 8 in. peeled at booster end	Detonation did not propagate
30	30	840	360	"	2670	590	870	19 in. O. K., 5 in. peeled at booster end	Detonation did not propagate
31	40	530	354	"	3810	650	650	14 in. O. K., 7 in. peeled, 1 in. shrapnellized	Detonation did not propagate
32	50	363	363	"	3050	690	350	16 in. O. K., 8 in. peeled back at booster end	Detonation did not propagate
33	55	338	414	"	4150	1040	550	15 in. O. K., 5 in. peeled, 4 in. shrapnellized	Decaying detonation
34	55	338	414	"	5190	1490	660	12 in. O. K., 8 in. peeled 4 in. shrapnellized	Decaying detonation

Note: All tests were performed using a 150 gm. RDX booster and 2 inch, schedule 40, stainless steel pipe (Type 304).

Table 5 (Continued)

Test No.	Slurry Composition Wt. (%) N. C.	Slurry Composition Wt. (gms) H_2O	Slurry Composition Wt. (gms) N. C.	Pipe Length	Measured Detonation Velocity (m/sec.) Initial	Measured Detonation Velocity (m/sec.) Midpoint	Measured Detonation Velocity (m/sec.) Final	Physical Evidence	Conclusion
35	65	257	478	24 in.	2610	2610	2610	Pipe completely shrapnellized	Detonation
36	65	428	798	40 in.	2910	2910	2910	Pipe completely shrapnellized	Detonation

Note: All tests were performed using a 150 gm. RDX booster and 2 inch, schedule 40, stainless steel pipe (Type 304).

Table 6

Results of detonation propagation tests on aqueous, settled slurries of RDX

Test No.	Slurry Composition Wt. (%) RDX	Wt. (gms) H_2O	Wt. (gms) RDX	Pipe Length	Measured Detonation Velocity (m/sec.) Initial	Midpoint	Final	Physical Evidence	Conclusion
37	10	1244	138	24 in.	7670	1730	620	11 in. O. K., 9 in. peeled, 4 in. shrapnellized	Decaying detonation
38	10	1244	138	"	6660	2600	1200	5 in. O. K., 7 in. peeled, 12 in. shrapnellized	Decaying detonation
39	15	1204	212	"	6280	1820	1180	10 in. O. K., 9 in. peeled, 5 in. shrapnellized	Decaying detonation
40	20	1162	291	"	8180	8180	5130	Pipe completely shrapnellized	Detonation
41	20	1941	486	40 in.	8160	8160	6150	Pipe completely shrapnellized	Detonation

Note: All tests were performed using a 150 gm. RDX booster and 2 inch, schedule 40, stainless steel pipe (Type 304).

Table 7

Results of detonation propagation tests on aqueous, settled slurries of HMX

Slurry Composition Wt. (%) HMX	Wt. (gms) H_2O	Wt. (gms) HMX	Pipe Length	Measured Detonation Velocity (m/sec.) Initial	Midpoint	Final	Physical Evidence	Conclusion
5	1284	68	24 in.	2830	1630	1350	13 in. O. K., 9 in. peeled, 2 in. shrapnellized	Detonation did not propagate
5	1284	68	"	8340	8340	6120	2 frag. strips, each 4 in. wide by 22 in. long, 2 in. shrapnellized	Detonation
5	2144	113	40 in.	3460	1380	1380	32 in. O. K., 6 in. peeled, 2 in. shrapnellized	Detonation did not propagate
10	1247	139	24 in.	8020	8020	8020	Frag. strips 1 in. wide x 16 in. long, 8 in. shrapnellized	Detonation
10	2079	231	40 in.	8600	8600	6130	Frag. strips of random widths and lengths	Detonation
15	1209	213	24 in.	9290	9290	7080	Pipe completely shrapnellized	Detonation
20	1166	292	"	9290	9290	7240	Pipe completely shrapnellized	Detonation

Note: All tests were performed using a 150 gm. RDX booster and 2 inch, schedule 40, stainless steel pipe (Type 304).

Table 7 (Continued)

Test No.	Slurry Composition Wt. (%) HMX	Slurry Composition Wt. (gms) H_2O	Slurry Composition Wt. (gms) HMX	Pipe Length	Measured Detonation Velocity (m/sec.) Initial	Measured Detonation Velocity (m/sec.) Midpoint	Measured Detonation Velocity (m/sec.) Final	Physical Evidence	Conclusions
49	25	1124	375	24 in.	9800	9800	6620	Pipe completely shrapnellized	Detonation

Note: All tests were performed using a 150 gm. RDX booster and 2 inch, schedule 40, stainless steel pipe (Type 304).

Table 8

Results of detonation propagation tests on aqueous, settled slurries of M-1 propellant

Test No.	Slurry Composition Wt. (%) M-1	Wt. (gms) H_2O	Wt. (gms) M-1	Pipe Length	Measured Detonation Velocity (m/sec.) Initial	Midpoint	Final	Physical Evidence	Conclusion
50	15	1175	207	24 in.	4940	1820	1000	13 in. O. K., 6 in. peeled, 5 in. shrapnellized	Detonation did not propagate
51	30	957	410	"	4860	2030	730	7 in. O. K., 5 in. peeled, 12 in. shrapnellized	Decaying detonation
52	35	899	485	"	5090	2310	620	3 in. O. K., 6 in. peeled, 15 in. shrapnellized	Decaying detonation
53	40	842	562	"	*	*	*	Pipe completely shrapnellized	Detonation
54	40	842	562	"	5290	5290	5290	Pipe completely shrapnellized	Detonation
55	40	1498	1000	40 in.	5700	2430	690	12 in. O. K., 10 in. peeled, 18 in. shrapnellized	Decaying detonation
56	45	1398	1144	"	5640	5640	5640	Pipe completely shrapnellized	Detonation

* Velocity probe malfunctioned

Note: All tests were performed using a 150 gm. RDX booster and 2 inch, schedule 40, stainless steel pipe (Type 304).

Table 9

Results of detonation propagation tests on aqueous, settled slurries of nitrocellulose containing cotton linters

Test No.	Slurry Composition Wt. (%) N. C.	Wt. (gms) H_2O	Wt. (gms) N. C.	Pipe Length	Measured Detonation Velocity (m/sec.) Initial	Midpoint	Final	Physical Evidence	Conclusion
57	10	1469	163	24 in.	3330	1580	1280	17 in. O. K., 6 in. peeled, 1 in. shrapnellized	Detonation did not propagate
58	20	1123	281	"	2370	1000	1000	16 in. O. K., 7 in. peeled, 1 in. shrapnellized	Detonation did not propagate
59	30	840	360	"	2780	1115	945	15 in. O. K., 7 in. peeled, 2 in. shrapnellized	Detonation did not propagate
60	40	530	354	"	4500	590	590	15 in. O. K., 8 in. peeled, 1 in. shrapnellized	Detonation did not propagate
61	50	363	363	"	2945	780	490	14 in. O. K., 10 in. peeled at booster end	Detonation did not propagate
62	55	338	414	"	2860	620	310	14 in. O. K., 9 in. peeled, 1 in. shrapnellized	Detonation did not propagate
63	60	267	400	"	2810	900	240	5 in. O. K., 7 in. peeled, 12 in. shrapnellized	Decaying detonation

Note: All tests were performed using a 150 gm. RDX booster and 2 inch, schedule 40, stainless steel pipe (Type 304).

Table 9 (Continued)

Test No.	Slurry Composition Wt. (%) N. C.	Slurry Composition Wt. (gms) H_2O	Slurry Composition Wt. (gms) N. C.	Pipe Length	Measured Detonation Velocity (m/sec.) Initial	Measured Detonation Velocity (m/sec.) Midpoint	Measured Detonation Velocity (m/sec.) Final	Physical Evidence	Conclusion
64	65	257	478	24 in.	2910	2910	2910	Pipe completely shrapnellized	Detonation
65	65	428	798	40 in.	2860	2860	2860	Pipe completely shrapnellized	Detonation
66	71	153	377	24 in.	2920	2920	2920	Pipe completely shrapnellized	Detonation

Note: All tests were performed using a 150 gm. RDX booster and 2 inch, schedule 40, stainless steel pipe (Type 304).

Table 10

Results of detonation propagation tests on aqueous, settled slurries of nitrocellulose containing wood pulp

Test No.	Slurry Composition Wt. (%) N. C.	Wt. (gms) H_2O	Wt. (gms) N. C.	Pipe Length	Measured Detonation Velocity (m/sec.) Initial	Midpoint	Final	Physical Evidence	Conclusion
67	10	1469	163	24 in.	2800	1520	1000	19 in. O. K., 5 in. peeled at booster end	Detonation did not propagate
68	20	1123	281	"	2520	1130	1130	16 in. O. K., 7 in. peeled, 1 in. shrapnellized	Detonation did not propagate
69	30	840	360	"	2750	980	590	17 in. O. K., 7 in. peeled at booster end	Detonation did not propagate
70	40	530	354	"	4340	640	640	16 in. O. K., 8 in. peeled at booster end	Detonation did not propagate
71	50	363	363	"	2870	620	360	14 in. O. K., 10 in. peeled at booster end	Detonation did not propagate
72	55	338	414	"	2740	610	395	13 in. O. K., 11 in. peeled at booster end	Detonation did not propagate
73	60	267	400	"	2950	1040	300	4 in. O. K., 8 in. peeled, 12 in. shrapnellized	Decaying detonation

Note: All tests were performed using a 150 gm. RDX booster and 2 inch, schedule 40, stainless steel pipe (Type 304).

Table 10 (Continued)

Test No.	Slurry Composition Wt. (%) N. C.	Slurry Composition Wt. (gms) H_2O	Slurry Composition Wt. (gms) N. C.	Pipe Length	Measured Detonation Velocity (m/sec.) Initial	Measured Detonation Velocity (m/sec.) Midpoint	Measured Detonation Velocity (m/sec.) Final	Physical Evidence	Conclusion
74	65	257	478	24 in.	3115	3115	3115	Pipe completely shrapnellized	Detonation
75	65	428	798	40 in.	3050	3050	3050	Pipe completely shrapnellized	Detonation

Note: All tests were performed using a 150 gm. RDX booster and 2 inch, schedule 40, stainless steel pipe (Type 304).

Table 11

Summary of detonation propagation test results

Sample Material	Slurry Type	Slurry Concentration (Wt. %) for Propagation: No Propagation	Partial Propagation	Complete Propagation *
RDX	Gelled	20	25	30
RDX	Settled	10	15	20
HMX	Gelled	20	25	30
HMX	Settled	5	-	5 - 10
M-1	Gelled	20 - 30	35	40
M-1	Settled	15 - 30	35 - 40	40 - 45
N. C. **	Gelled	10 - 55	60	60 - 65
N. C. **	Settled	10 - 55	60	65
N. C. ***	Gelled	10 - 55	60	65
N. C. ***	Settled	10 - 55	60	65

* RDX, HMX and M-1 Propagate High Order Detonations.
Nitrocellulose Propagates Low Order Detonations.

** Nitrocellulose Containing Cotton Linters.

*** Nitrocellulose Containing Wood Pulp.

Note: Three trials were performed with 5% settled HMX; one propagated completely, two failed to propagate.

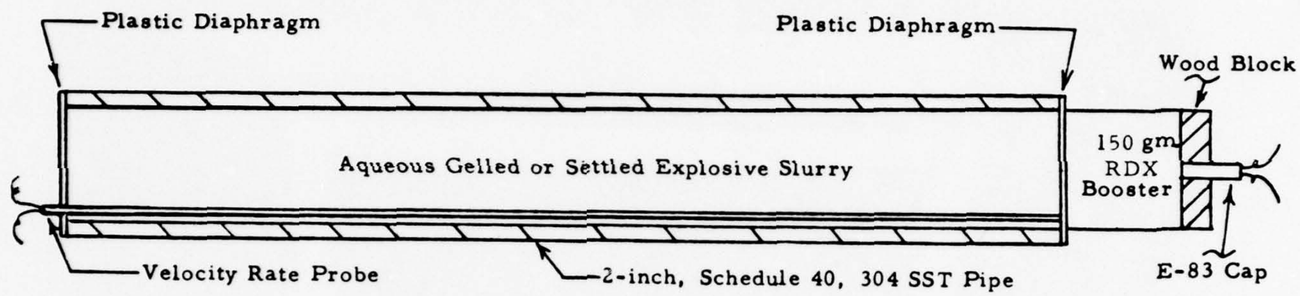


Fig 1 Horizontally fired detonation propagation test set-up

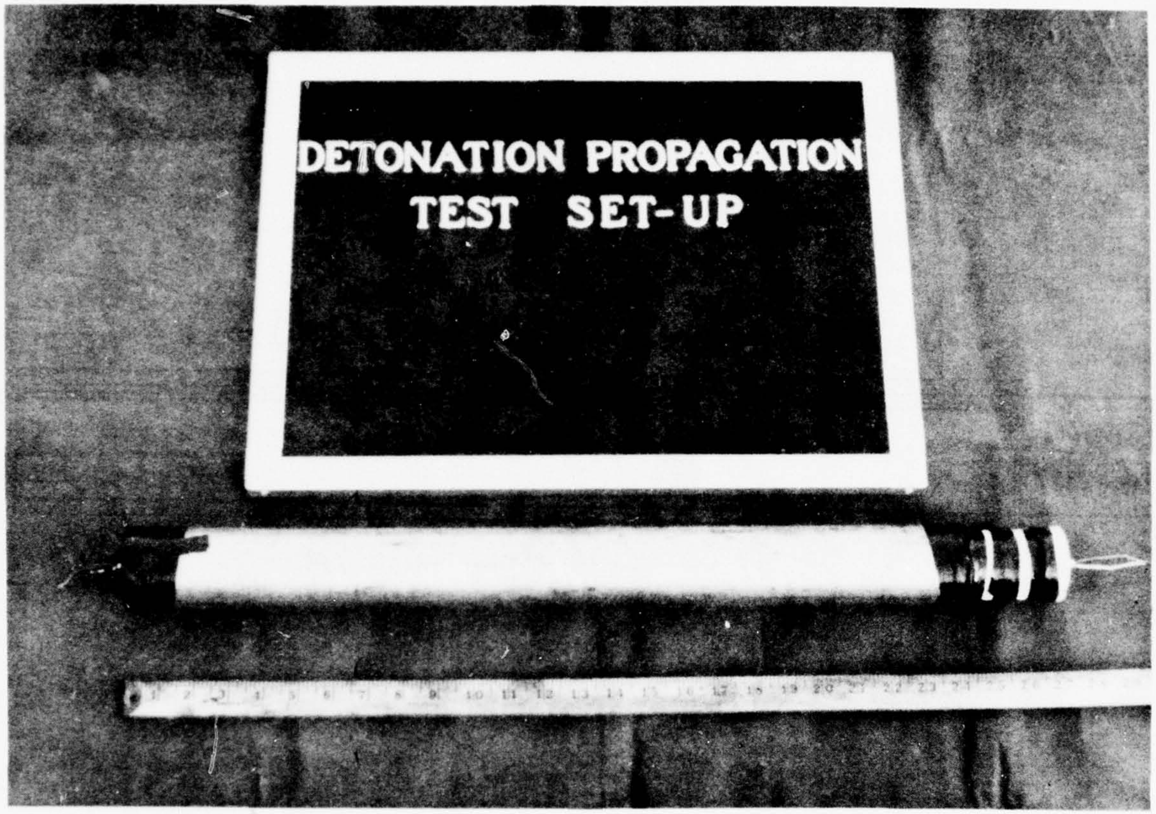


Fig 2 Horizontally fired detonation propagation test set-up

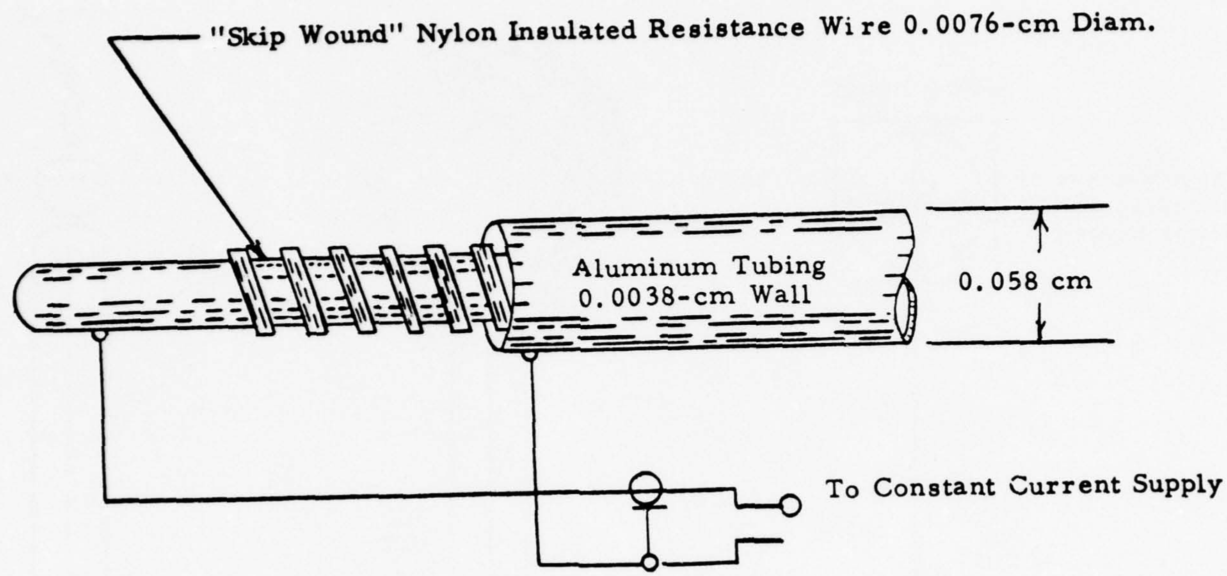


Fig 3 Details of detonation velocity probe

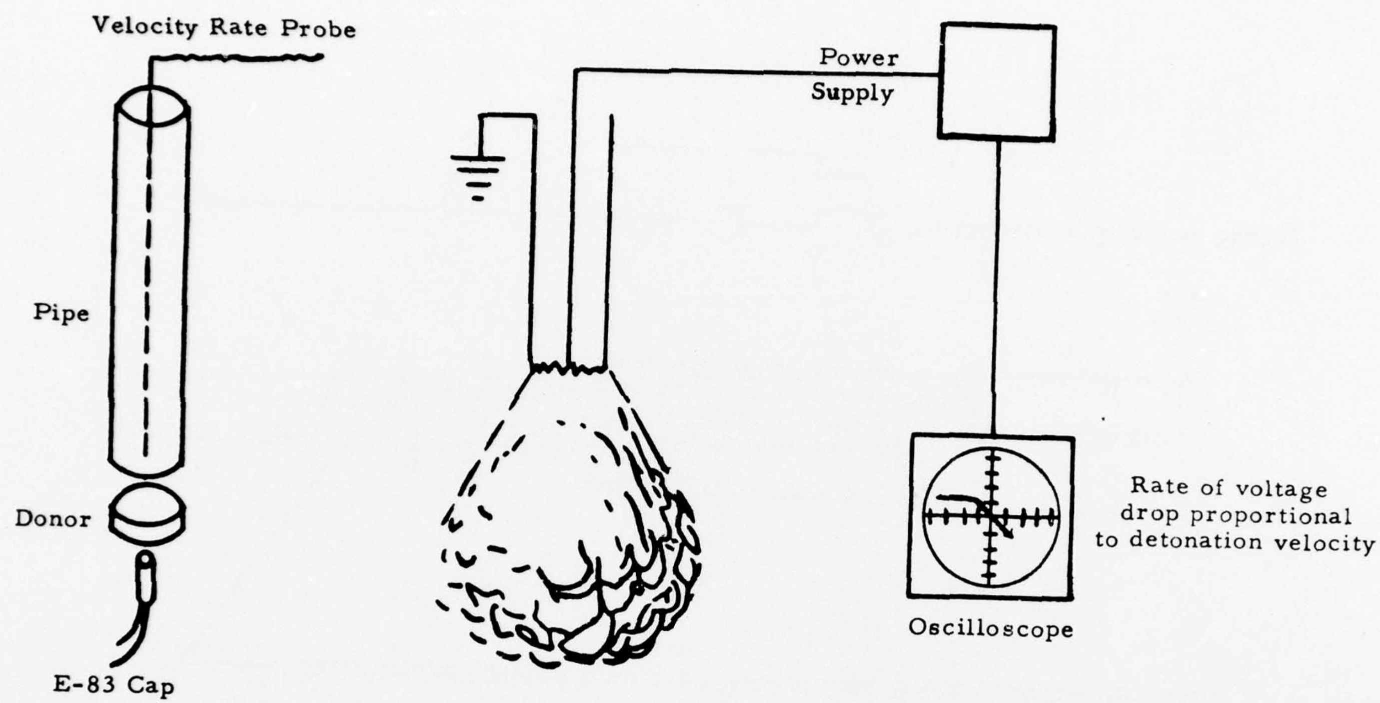


Fig 4 Detonation velocity test system

Fig 5 Physical evidence from aqueous, gelled RDX slurry test series

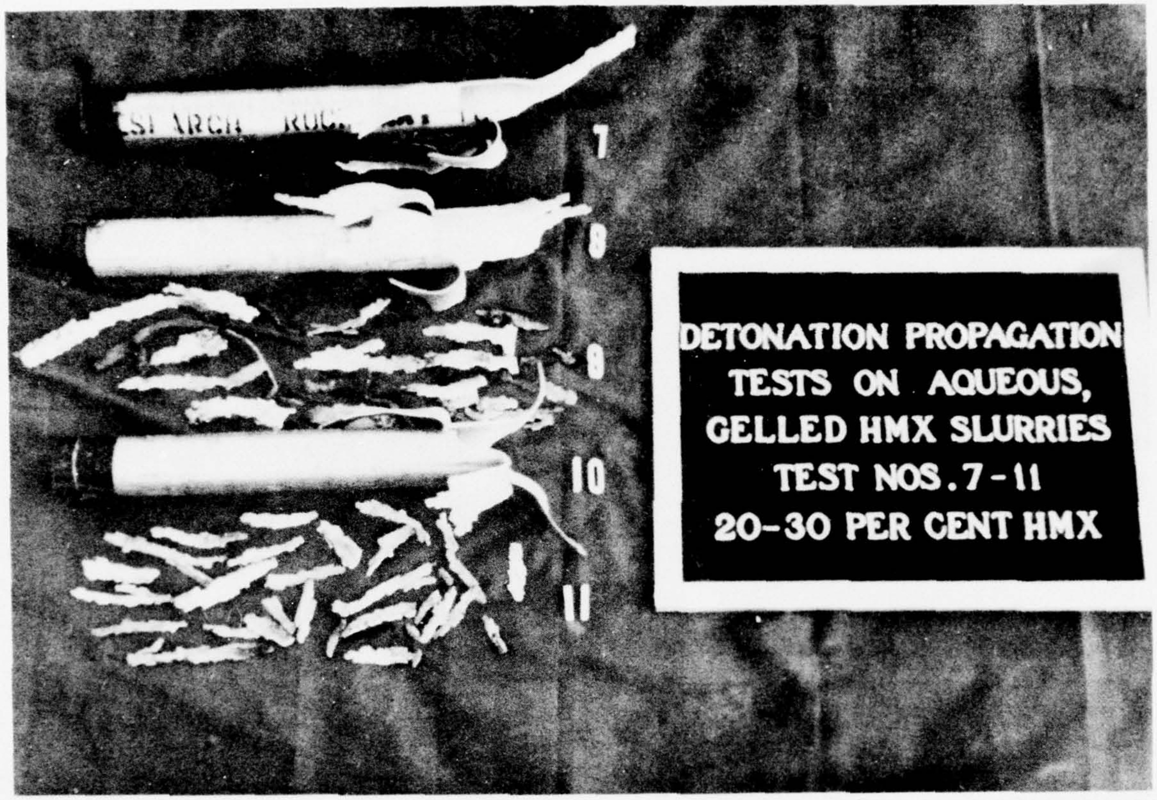


Fig 6 Physical evidence from aqueous, gelled HMX slurry test series

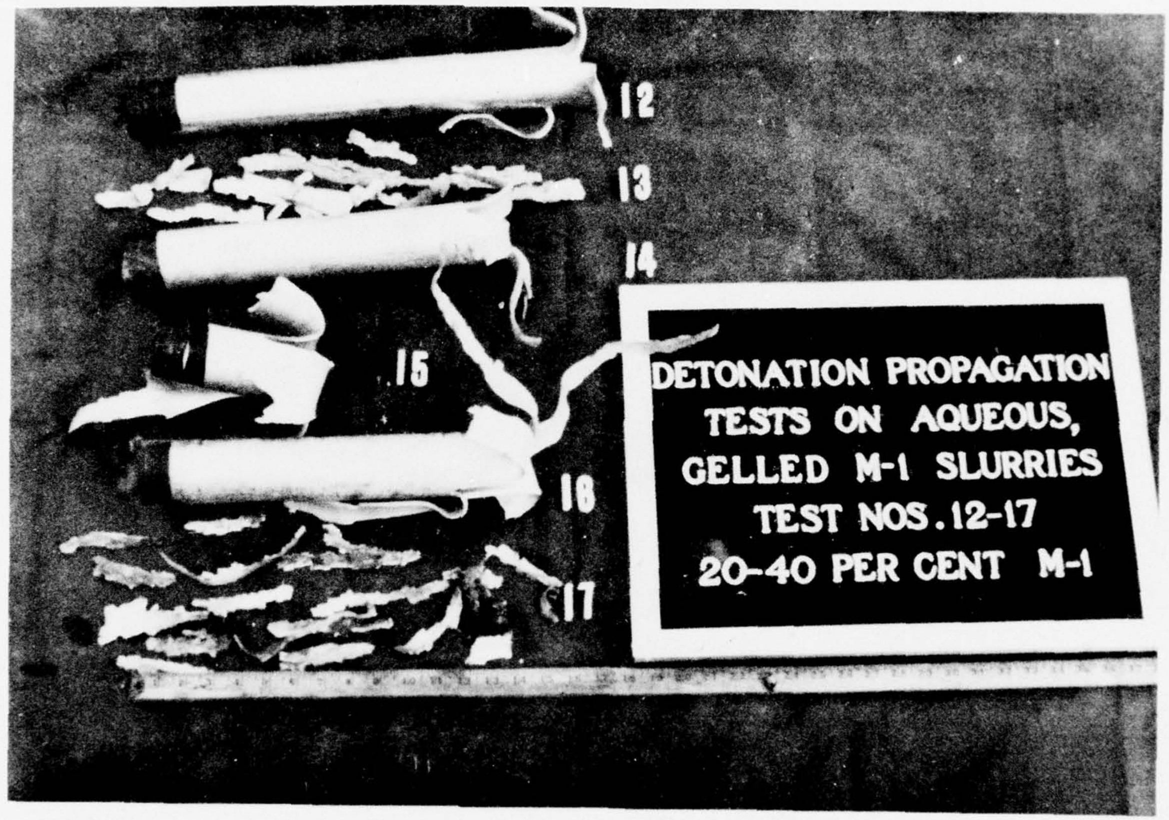


Fig 7 Physical evidence from aqueous, gelled M-1 slurry test series

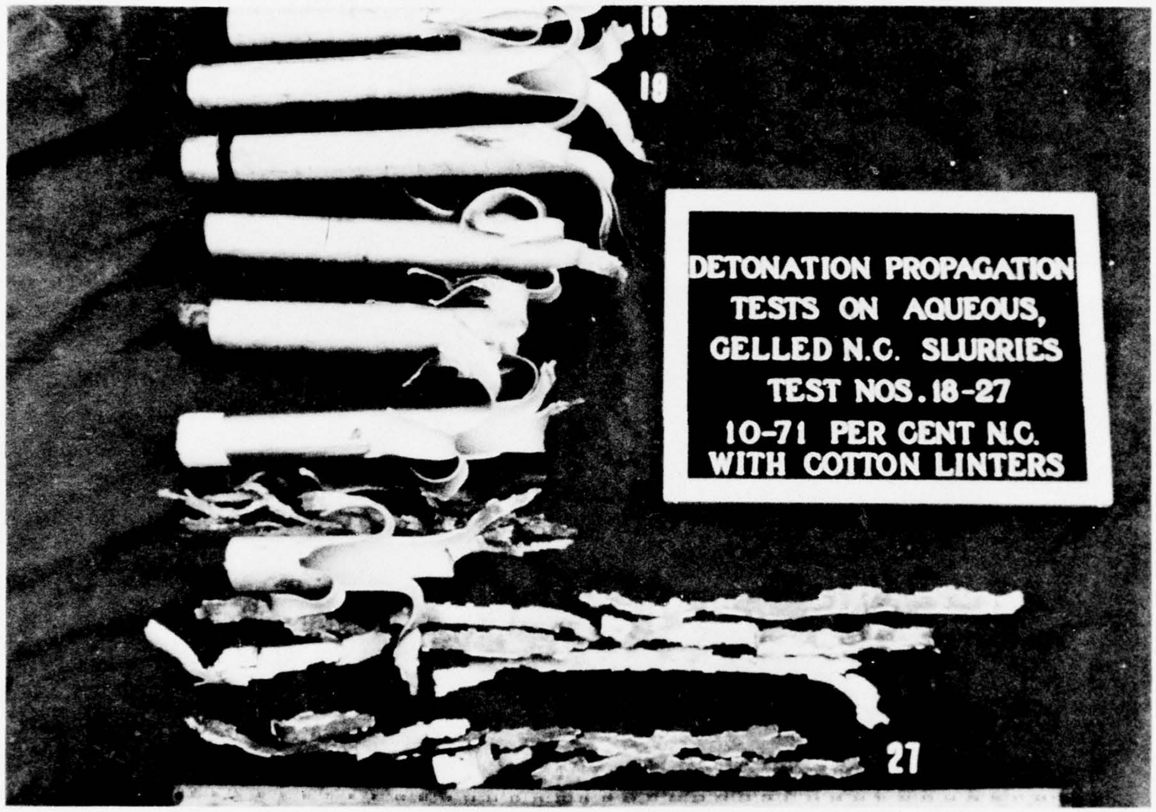


Fig 8 Physical evidence from aqueous, gelled nitrocellulose (containing cotton linters) slurry test series

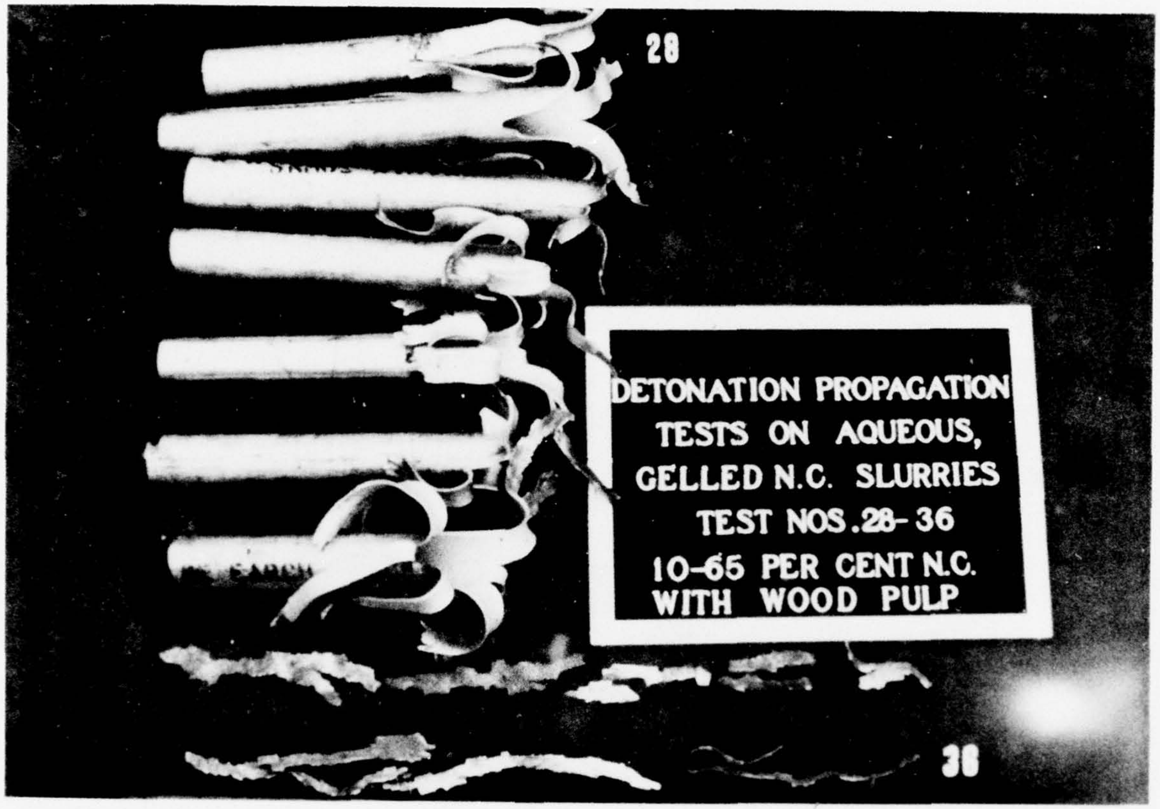


Fig 9 Physical evidence from aqueous, gelled nitrocellulose (containing wood pulp) slurry test series

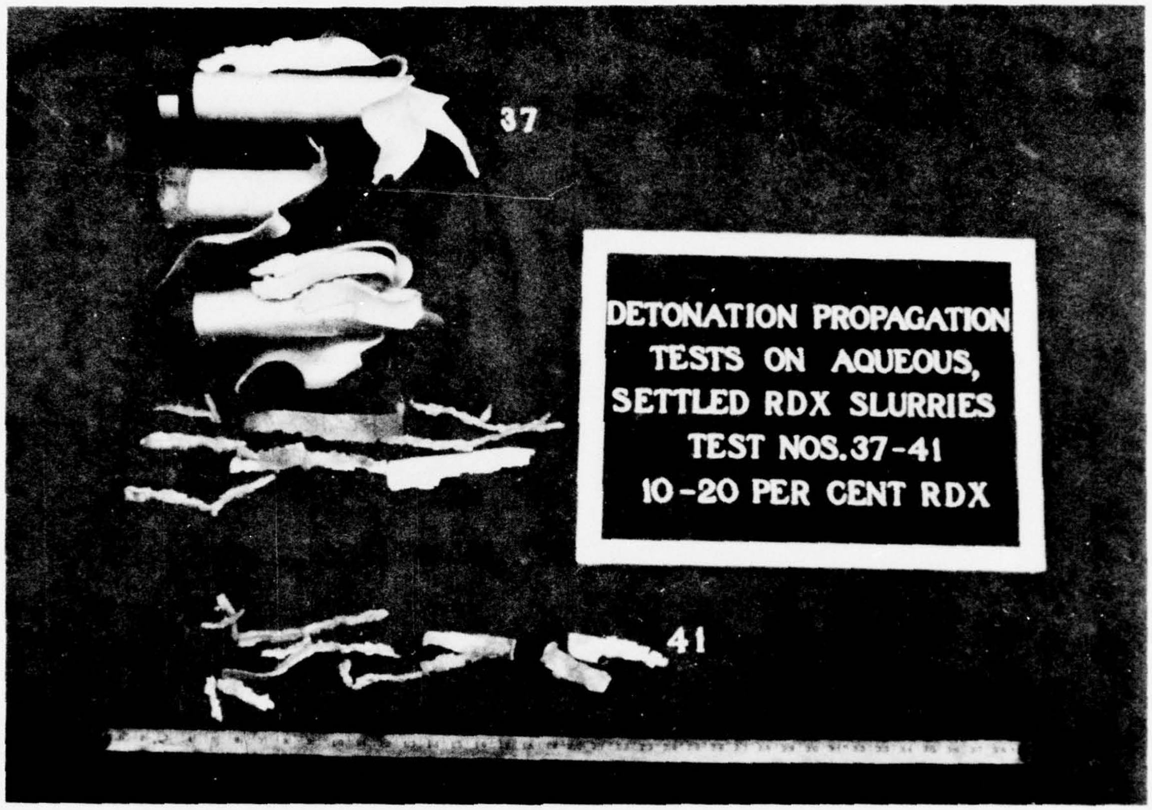


Fig 10 Physical evidence from aqueous, settled RDX slurry test series

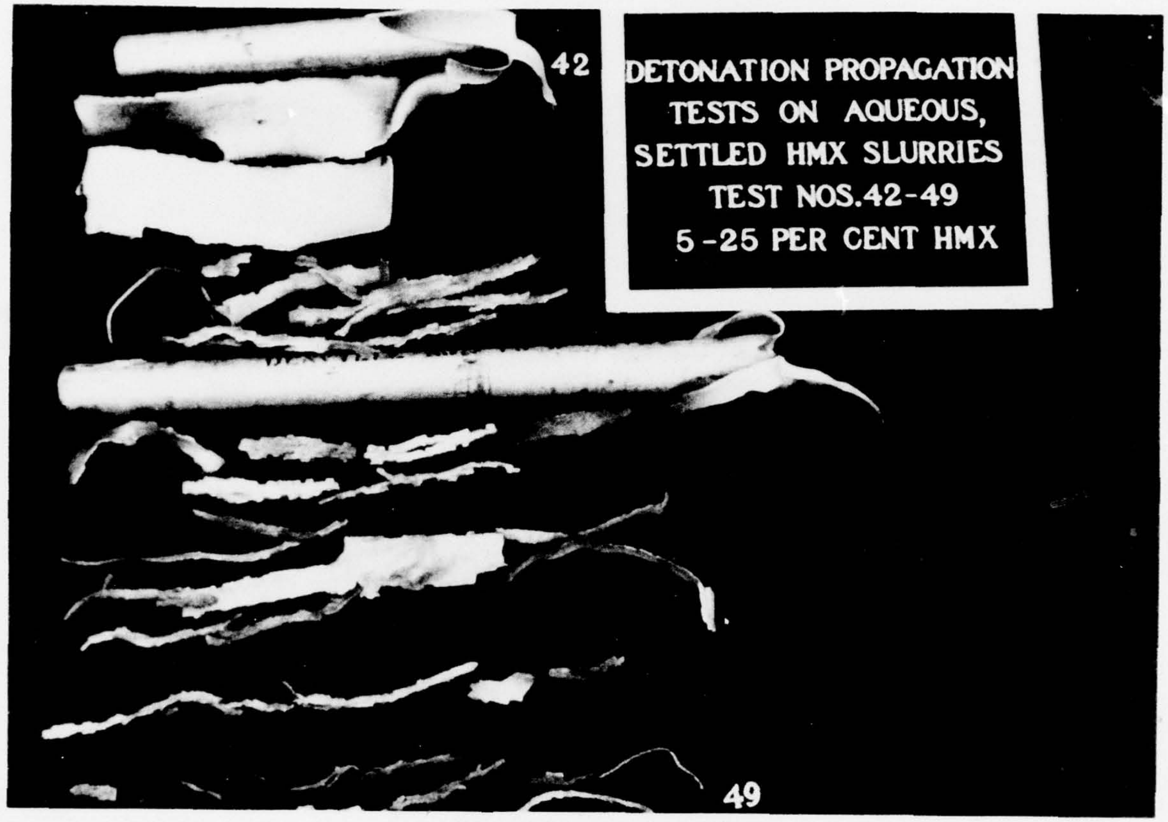


Fig 11 Physical evidence from aqueous, settled HMX slurry test series

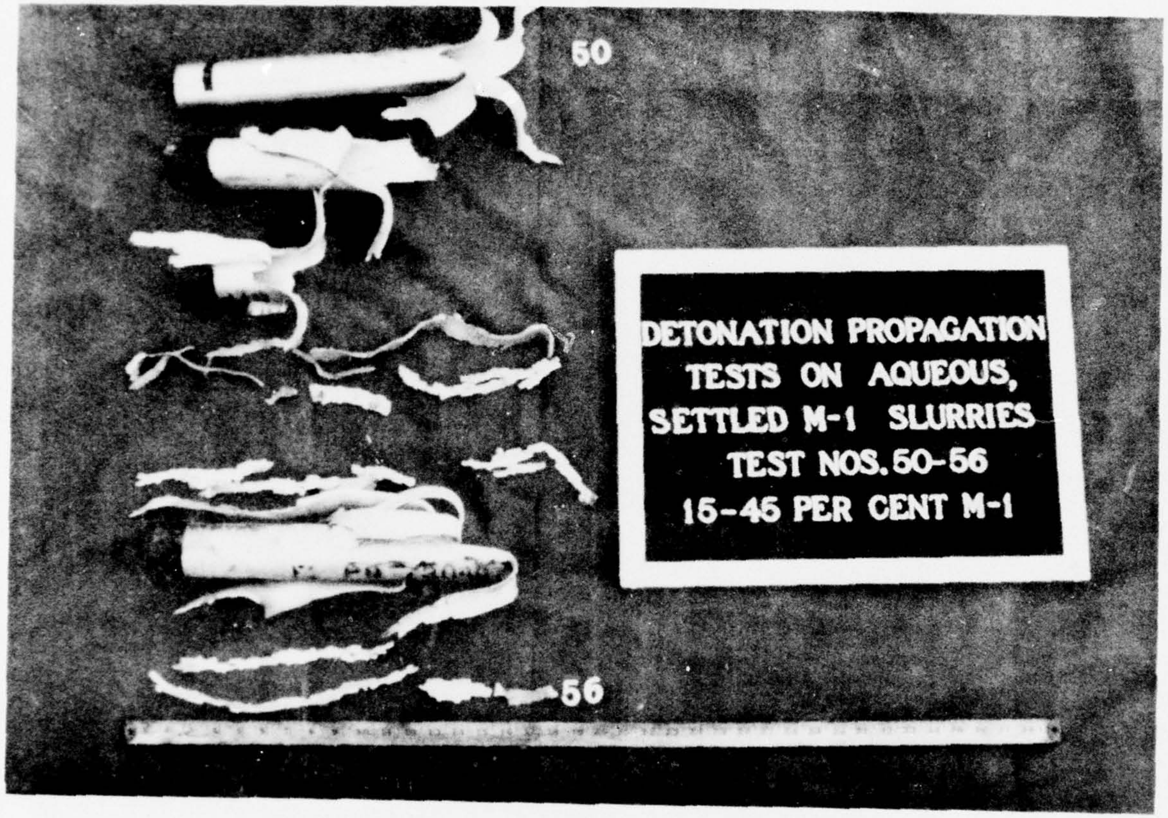


Fig 12 Physical evidence from aqueous, settled M-1 slurry test series

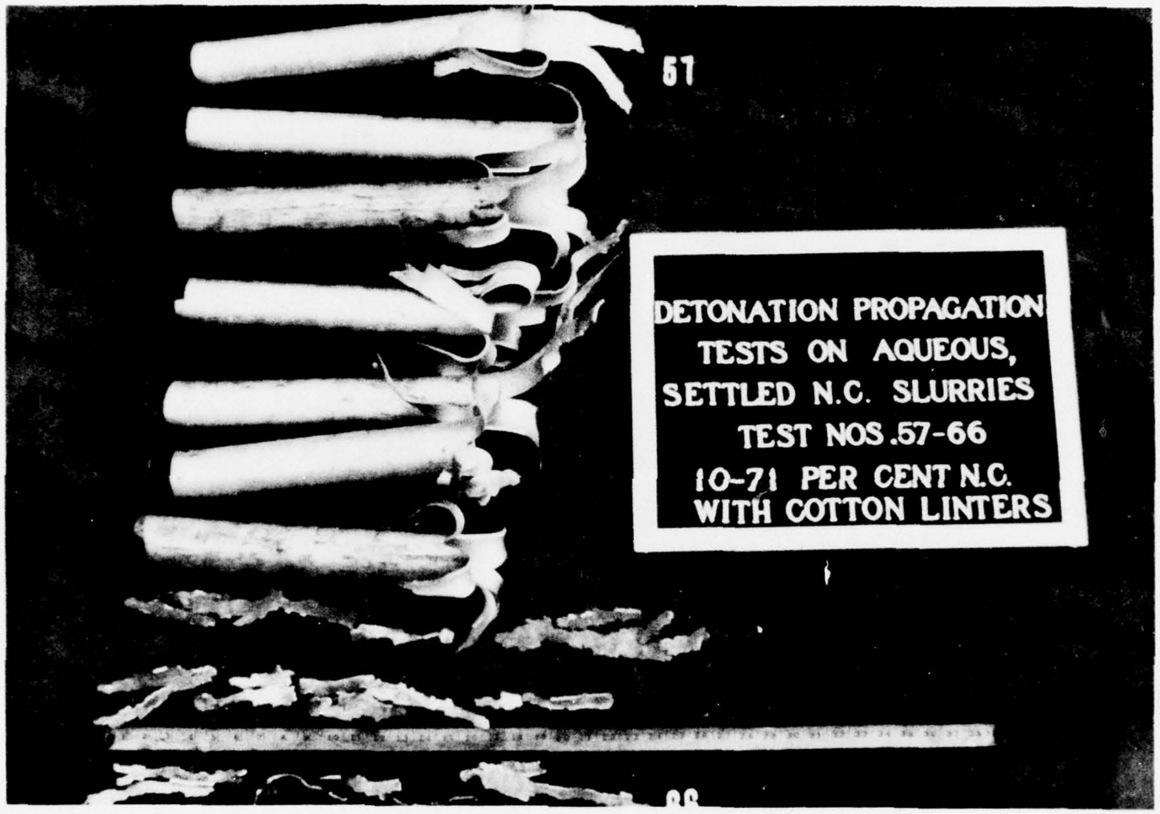


Fig 13 Physical evidence from aqueous, settled nitrocellulose (containing cotton linters) slurry test series

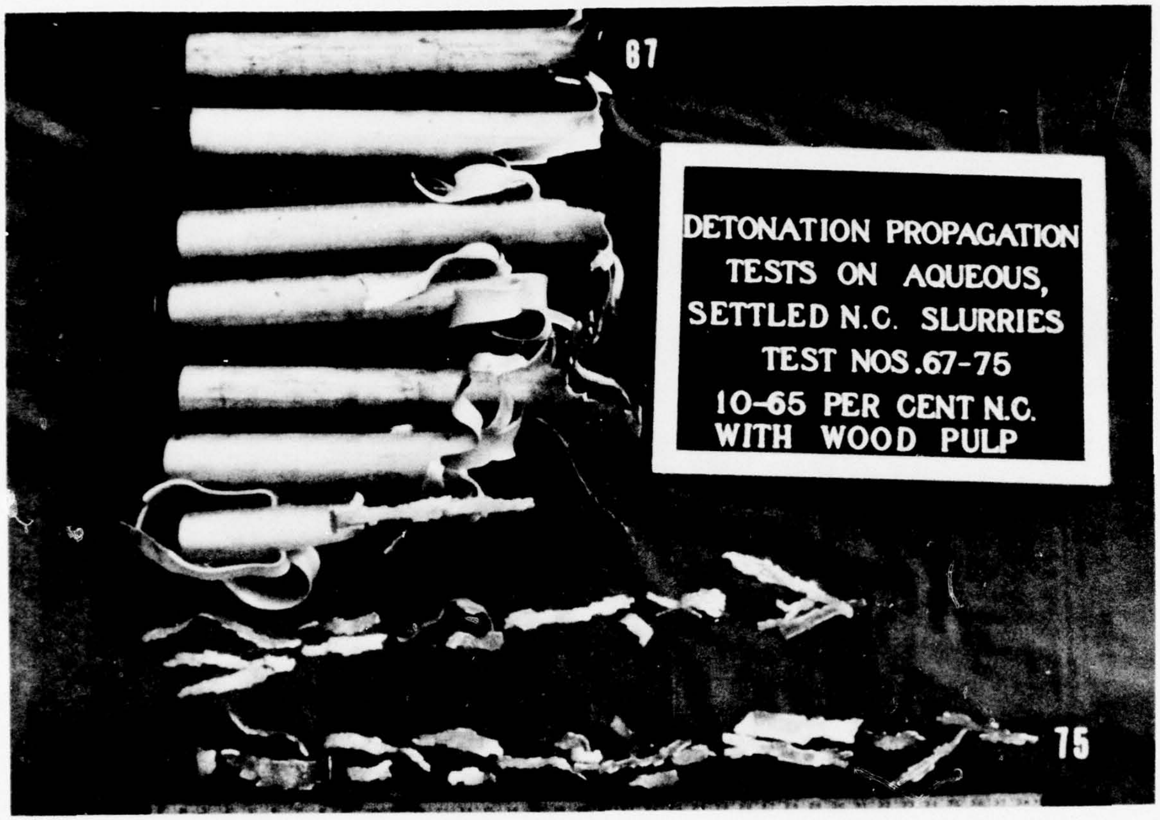
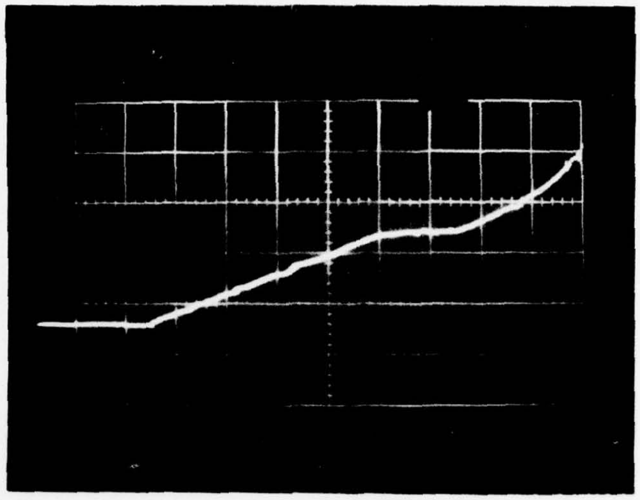
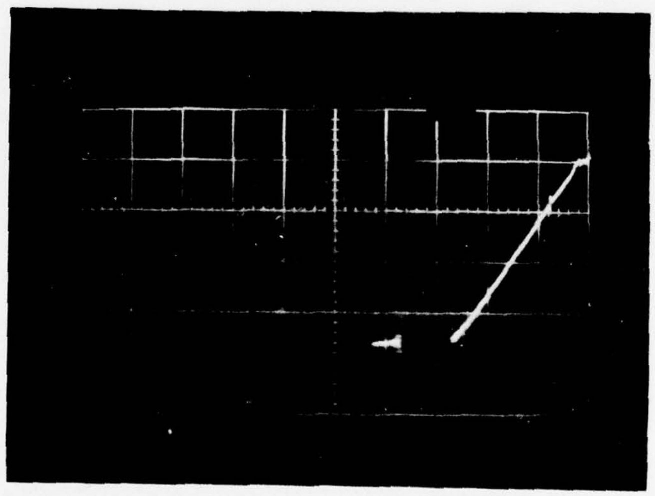


Fig 14 Physical evidence from aqueous, settled nitrocellulose (containing wood pulp) slurry test series

Wt % RDX		Test No.
20		2

Non-propagating reaction time ←
1 div = 50 μsec

30		4

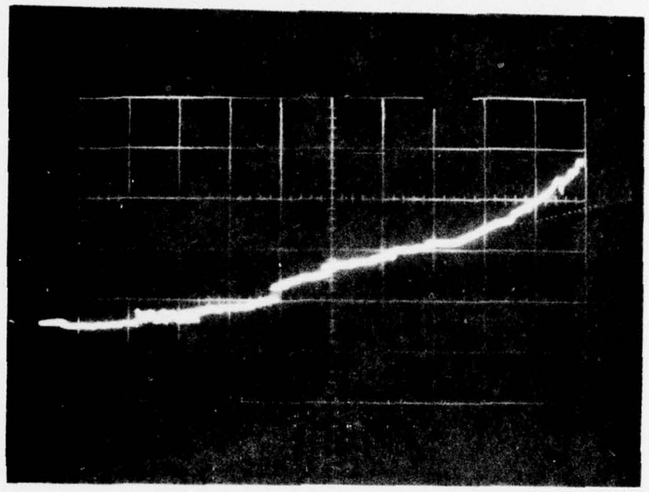
Propagating reaction time ←
1 div = 50 μsec

Fig 15 Detonation velocity traces for aqueous, gelled slurries of RDX

Wt %
HMX

Test
No.

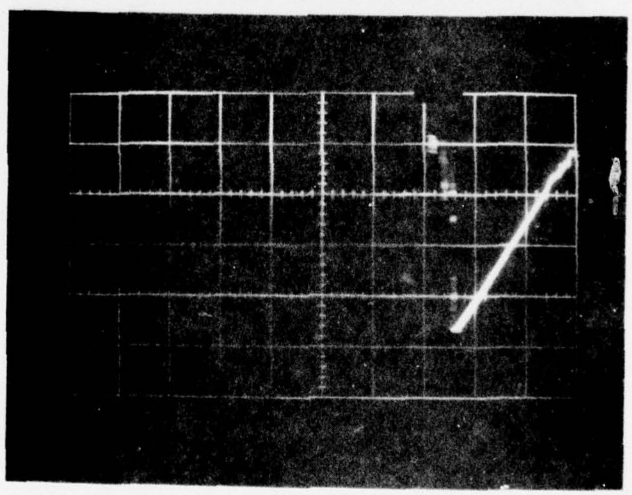
20



7

Non-propagating reaction time ←
1 div = 50 μsec

30



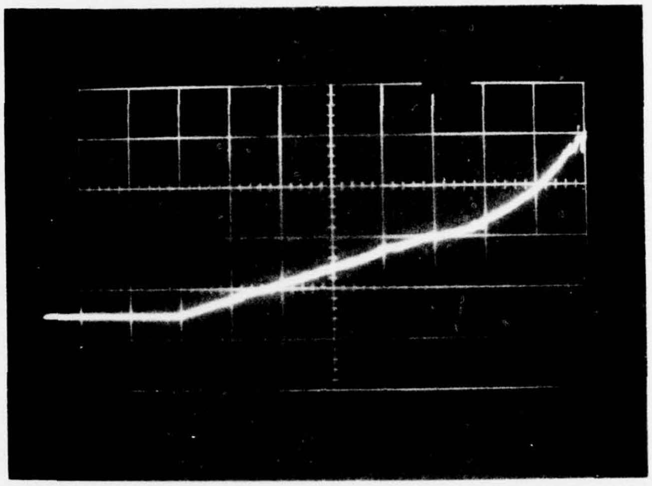
9

Propagating reaction time ←
1 div = 50 μsec

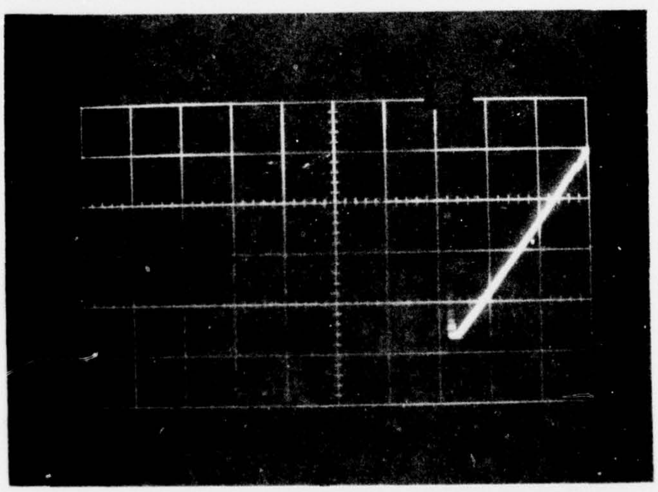
Fig 16 Detonation velocity traces for aqueous, gelled slurries of HMX

Wt %
M-1

Test
No.

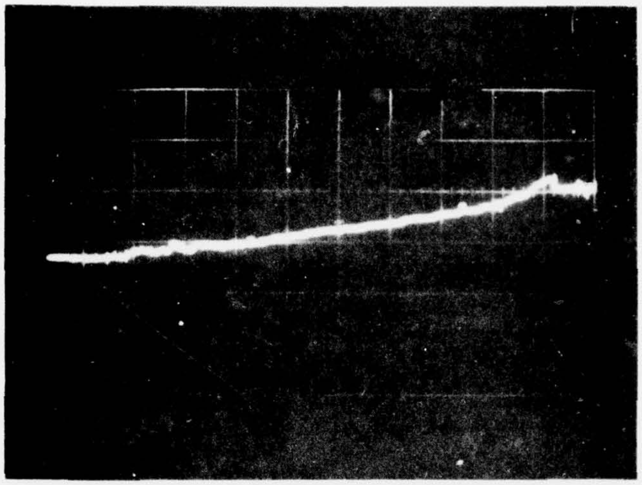
30  14

Non-propagating reaction time ←
1 div = 50 μsec

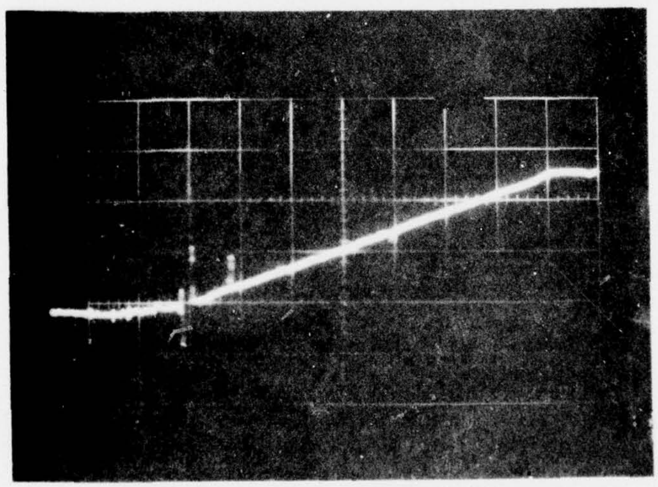
40  13

Propagating reaction time ←
1 div = 50 μsec

Fig 17 Detonation velocity traces for aqueous, gelled slurries of M-1 propellant

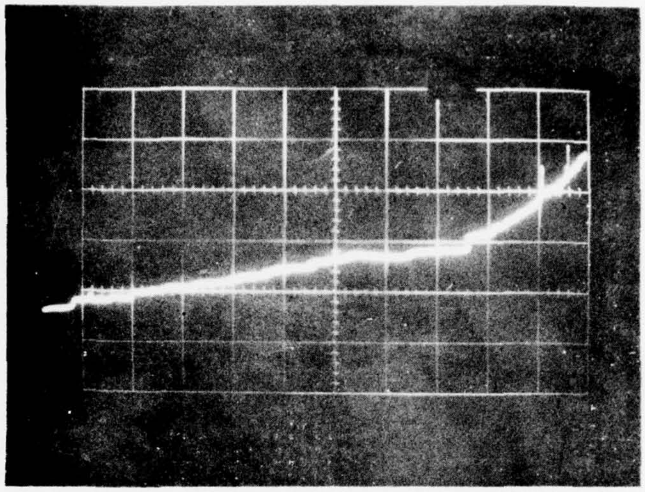
Wt % N.C.		Test No.
55		23

Non-propagating reaction time ←
1 div = 50 μsec

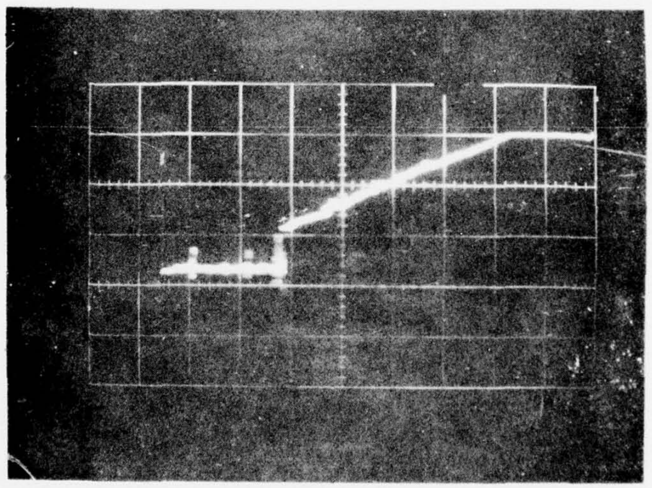
65		26

Propagating reaction time ←
1 div = 50 μsec

Fig 18 Detonation velocity traces for aqueous, gelled slurries of nitrocellulose containing cotton linters

Wt % N.C.		Test No.
55		33

Non-propagating reaction time ←
1 div = 50 μsec

65		36

Propagating reaction time ←
1 div = 50 μsec

Fig 19 Detonation velocity traces for aqueous, gelled slurries of nitrocellulose containing wood pulp

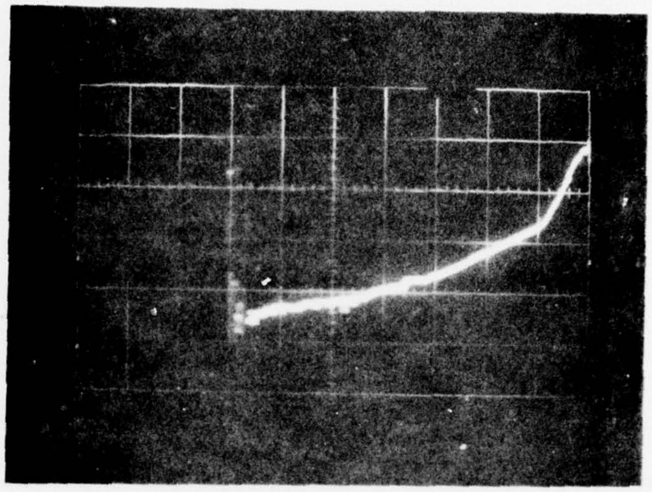
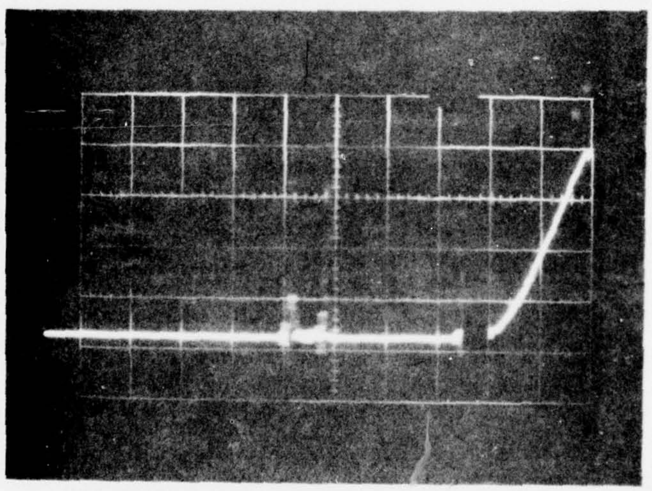
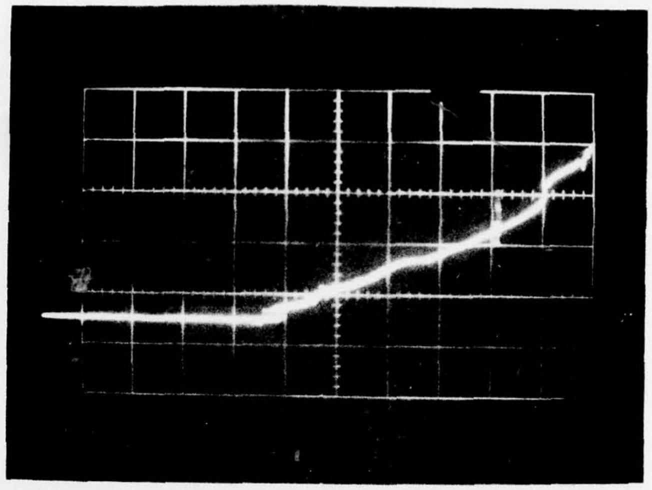
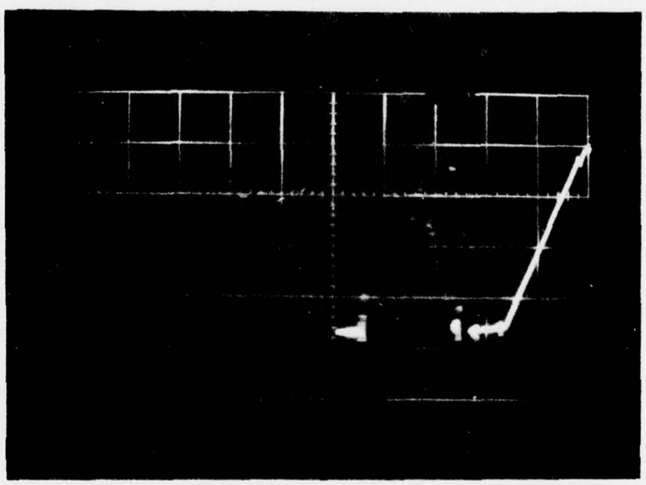
Wt % RDX		Test No.
10		37
	Non-propagating reaction time ← 1 div = 50 μsec	
20		40
	Propagating reaction time ← 1 div = 50 μsec	

Fig 20 Detonation velocity traces for aqueous, settled slurries of RDX

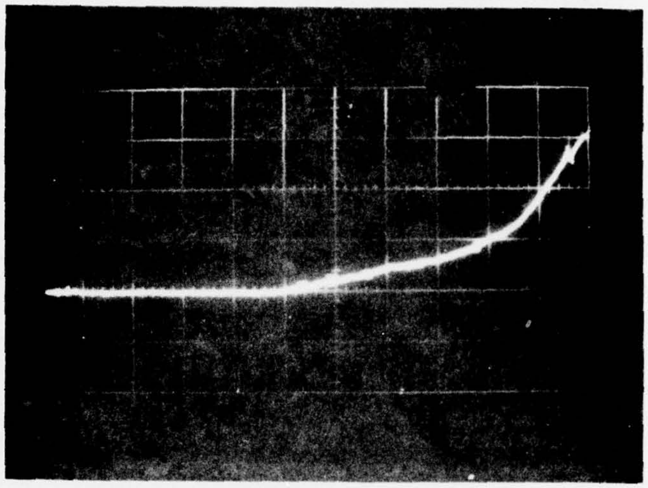
Wt % HMX		Test No.
5		42

Non-propagating reaction time ←
1 div = 50 μsec

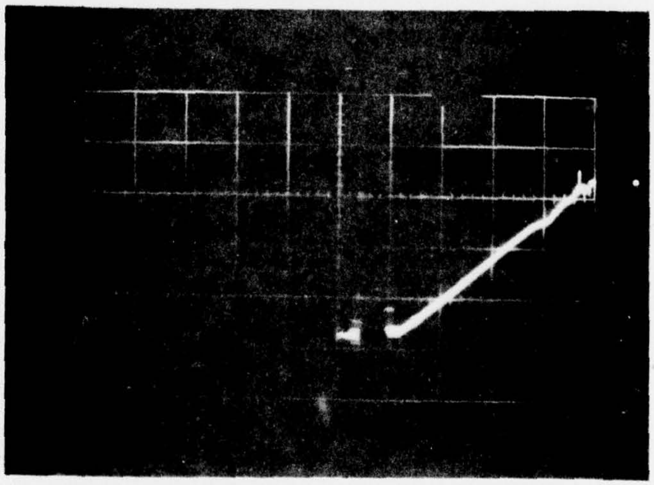
10		45

Propagating reaction time ←
1 div = 50 μsec

Fig 21 Detonation velocity traces for aqueous, settled slurries of HMX

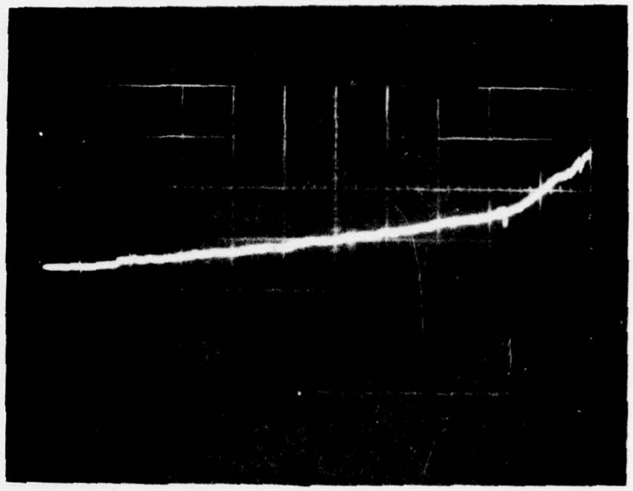
Wt % M-1		Test No.
30		51

Non-propagating reaction time ←
1 div = 50 μsec

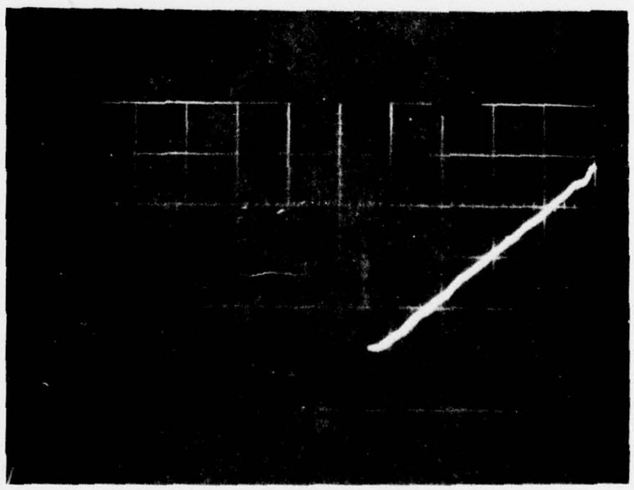
45		56

Propagating reaction time ←
1 div = 50 μsec

Fig 22 Detonation velocity traces for aqueous, settled slurries of M-1 propellant

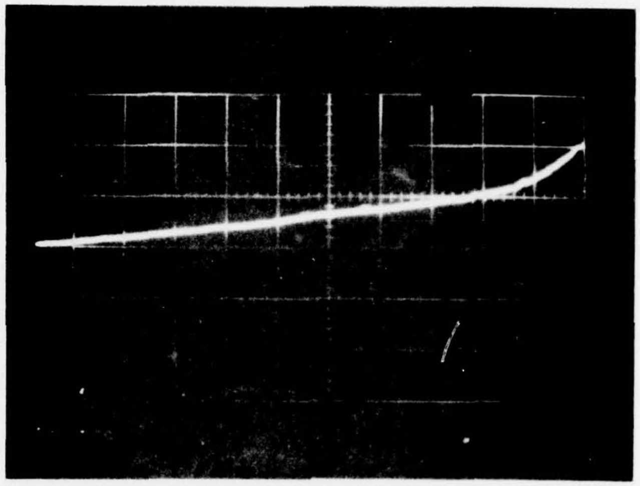
Wt % N.C.		Test No.
55		62

Non-propagating reaction time ←
1 div = 50 μsec

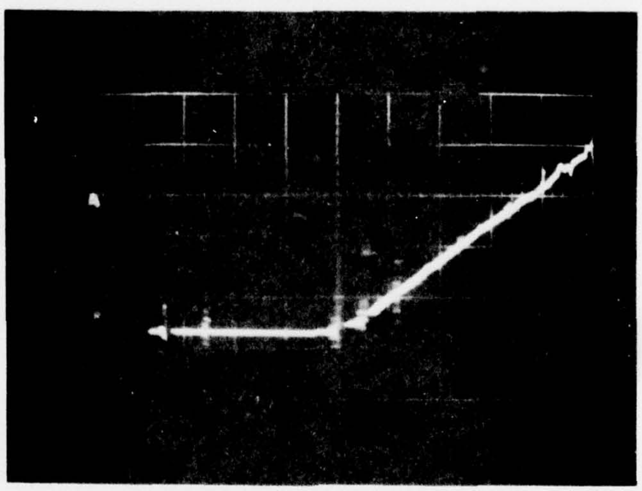
65		64

Propagating reaction time ←
1 div = 50 μsec

Fig 23 Detonation velocity traces for aqueous, settled slurries of nitrocellulose containing cotton linters

Wt % N.C.		Test No.
55		72

Non-propagating reaction time →
1 div = 50 μsec

65		74

Propagating reaction time →
1 div = 50 μsec

Fig 24 Detonation velocity traces for aqueous, settled slurries of nitrocellulose containing wood pulp

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